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ORIGINAL ARTICLE

A cephalometric study of Class II malocclusions treated with mandibular surgery

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Introduction: Class II malocclusion is often associated with retrognathic mandible. Some of these problems require surgical correction. The purposes of this study were to investigate treatment outcomes in patients with Class II malocclusions whose treatment included mandibular advancement surgery and to identify predictors of good outcomes. **Methods:** Pretreatment and posttreatment cephalometric radiographs of 90 patients treated with mandibular advancement surgery by 57 consultant orthodontists in the United Kingdom before September 1998 were digitized, and cephalometric landmarks were identified. Paired samples *t* tests were used to compare the pretreatment and posttreatment cephalometric values for each patient. For each cephalometric variable, the proportion of patients falling within the ideal range was identified. Multiple logistic regression analysis was performed to identify predictors of achieving ideal range outcomes for the key skeletal (ANB and SNB angles), dental (overjet and overbite), and soft-tissue (Holdaway angle) measurements. **Results:** An overjet within the ideal range of 1 to 4 mm was achieved in 72% of patients and was more likely with larger initial ANB angles. Horizontal correction of the incisor relationship was achieved by a combination of 75% skeletal movement and 25% dentoalveolar change. An ideal posttreatment ANB angle was achieved in 42% of patients and was more likely in females and those with larger pretreatment ANB angles. Ideal soft-tissue Holdaway angles (7° to 14°) were achieved in 49% of patients and were more likely in females and those with smaller initial SNA angles. Mandibular incisor decompensation was incomplete in 28% of patients and was more likely in females and patients with greater pretreatment mandibular incisor proclination. Correction of increased overbite was generally successful, although anterior open bites were found in 16% of patients at the end of treatment. These patients were more likely to have had initial open bites. **Conclusions:** Mandibular surgery had a good success rate in normalizing the main dental and skeletal relationships. Less ideal soft-tissue profile outcomes were associated with larger pretreatment SNA-angle values, larger final mandibular incisor inclinations, and smaller final maxillary incisor inclinations. The use of mandibular surgery to correct anterior open bite was associated with poor outcomes. (Am J Orthod Dentofacial Orthop 2007;131:7.e1-7.e8)

Class II malocclusions constitute a large proportion of the typical orthodontic caseload. Approximately 70% of these patients have an associated skeletal discrepancy that is commonly a result of a retrognathic mandible.[1] Although many Class II malocclusions can be satisfactorily managed with nonsurgical orthodontic treatment, some patients have severe skeletal discrepancies that require surgical orthodontic treatment. The main objectives of surgical orthodontic treatment are to normalize the facial profile, occlusion, and function. Correction of the main dentoskeletal parameters to within their normal range of values is usually regarded as a main aim of treatment. Patients typically undergo an initial phase of fixed appliance treatment to align and coordinate the arches and to remove any dentoalveolar compensation of the incisors (decompensation). Single-jaw mandibular advancement surgery is commonly used for surgical Class II correction, although correction can also involve bimaxillary surgery.

In this study, we investigated the cephalometric outcomes of a large sample of Class II surgical orthodontic patients. It was part of a larger retrospective, multi-center study carried out in the United Kingdom (UK) to examine the provision and outcome of surgical orthodontic treatment in the UK's hospital consultant orthodontic service.

Our aims were to investigate the treatment outcome of Class II surgical orthodontic patients treated with

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Table I. Cephalometric measurements and ideal ranges

Variable	*Definition*	*Ideal range*
SNA angle (°)	Maxillary prominence (sella-nasion-Point A)	78-84
SNB angle (°)	Mandibular prominence (sella-nasion-Point B)	75-81
ANB angle (°)	Skeletal antero-posterior relationship	1-5
MM angle (°)	Mandibular-maxillary plane angle	23-31
LFH% (N-Me)/(ANS-Me) (%)	Lower anterior facial proportion	53-57
Overjet (mm)	Overjet	1-4
Overbite (mm)	Overbite	1-4
U1:Mx (°)	Maxillary incisor inclination (relative to maxillary plane)	103-115
L1:Mn (°)	Mandibular incisor inclination (relative to mandibular plane)	87-99
Holdaway angle (°)	Soft-tissue anteroposterior relationship	7-14

mandibular surgery and orthodontics, and to identify predictors of good outcomes.

SUBJECTS AND METHODS

Each consultant orthodontist in the UK providing surgical orthodontic treatment (n = 160) was asked to provide pretreatment and posttreatment cephalometric radiographs of 6 consecutively completed surgical orthodontic patients who had surgery before September 1998. One hundred ten consultants submitted 620 sets of cephalometric case records, and 90 patients (33 male, 57 female) treated by 57 orthodontists with single-jaw mandibular surgery met the inclusion criteria and were selected for the sample. The inclusion criteria were overjet of 6 mm or larger, no cleft lip and palate or craniofacial syndrome, and pretreatment cephalometric radiograph recorded at a minimum age of 15 years.

The pretreatment and posttreatment cephalometric radiographs for each patient were digitized by using Opal Image orthognathic planning software (version 1.3, COGSOFT, British Orthodontic Society, London, UK) on a PC with a digitizing screen (Numonics digitizing screen, SSi Microcad, Pewsey, UK) with an accuracy of 0.1 mm. The precision of this digitizer was evaluated in a previous investigation, and it was found to have excellent accuracy.[2]

All linear measurements were corrected for magnification. If a magnification scale was not present on a cephalometric film, the participating orthodontist was instructed to record a cephalometric radiograph of a standardized 15-cm rod that had been specifically engineered to allow calculation of the magnification factor of each cephalostat (Dontaur Engineering, Ballymena, Northern Ireland). The rods were produced with notches at 5 and 10 cm and with a specification of less than 0.1 mm error in length. If a different cephalostat had been used for a patient's pretreatment and posttreatment radiographs, the difference in length between sella and nasion of the 2 radiographs was used to determine whether the magnification had altered, and, if so, the values of any linear measurements were adjusted accordingly. The sella-nasion line is considered to be relatively stable beyond 7 years of age.

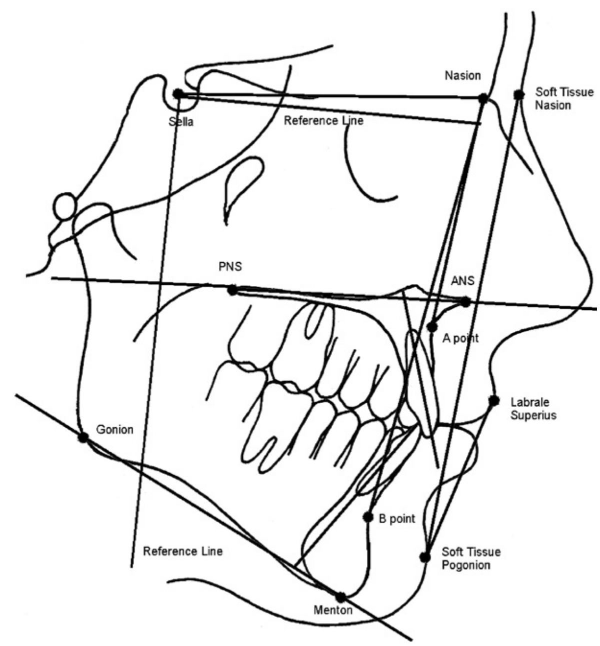

Fig. Landmarks and lines used in cephalometric analysis. See Table I for definitions.

The cephalometric variables that were measured are shown in Table I and the Figure. The maxillary plane was defined as posterior nasal spine to anterior nasal spine, and the mandibular plane was defined as gonion to menton. The Holdaway angle was defined as the angle soft-tissue nasion to soft-tissue pogonion to labrale superius (Fig). A horizontal reference line was constructed by rotating the sella-nasion line downward by 6°, and a vertical reference line was constructed perpendicularly through sella. The horizontal and vertical movements of Point A, Point B, and the maxillary and mandibular incisor tips relative to these lines were used to measure the movements of the maxilla, the mandible, and the incisors respectively.

The error of the method was assessed by using replicate tracings and measurements on 30 randomly selected films with the method error values calculated with the formula described by Dahlberg[3]: $Se = \sqrt{(\Sigma d^2/2n)}$ where *Se* is the method error (or standard deviation of the difference of each of the paired measurements from its own pair mean), *d* is the difference between the first and second recordings, and *n* is the number of radiographs replicated.

In addition, paired *t* tests were used to detect any systematic differences between the original and the replicate measurements.[4]

Statistical analysis

Paired samples *t* tests were used to compare the pretreatment and posttreatment cephalometric values for each patient. In addition, for each pretreatment and posttreatment cephalometric variable, the proportion of patients in the ideal range was identified. For skeletal and dentoskeletal measurements, the ideal ranges were based on the Eastman normal values,[5] with the ideal range defined as within 1 SD of the normal mean. The ideal range of 7° to 14° for the soft-tissue Holdaway angle was based on the recommendation of its originator,[6] and the ideal ranges of 1 to 4 mm for overjet and overbite were those recommended by Proffit et al.[7] The ideal ranges for the variables are shown in Table I.

Multiple logistic regression analysis was carried out to identify predictors of achieving ideal range outcomes for the key skeletal measurements (ANB and SNB angles), dental measurements (overjet and overbite), and soft-tissue measurement (Holdaway angle). Twenty-three independent variables were entered into the regression analyses. These included 10 pretreatment cephalometric measurements (Table I), final maxillary and mandibular incisor inclinations and whether there was a pretreatment anterior open bite. The remaining 10 variables were sex, age at start of treatment, duration of presurgical and postsurgical orthodontic treatment, use of premolar extractions in the maxillary or mandibular arches, history of previous orthodontic treatment and extractions, whether a genioplasty was carried out, and the average number of surgical orthodontic patients treated by each surgeon per year.

RESULTS

By using the inclusion criteria, 90 Class II patients (33 male, 57 female) treated by 57 orthodontists with single-jaw mandibular surgery were identified from a total sample of 620 surgical orthodontic patients submitted by the consultant orthodontists. Eighty-four subjects (93%) were white, 3 were Indian, 2 were Pakistani, and 1 was black-Caribbean. The pretreatment cephalometric radiographs were recorded for the female patients at a mean age 25.9 years (range, 15.1-49.0 years) and for males at a mean age of 22.5 years (range, 15.1-47.0 years). The posttreatment cephalometric radiographs had been recorded at a mean time of 11.3 months after surgery (range, 0-40 months). Posttreatment cephalometric radiographs were recorded less than a year after surgery in 67% of the patients and more than 2 years after surgery in 19%. The mean time between pretreatment and posttreatment radiographs was 25.8 months (range, 13-56 months).

Thirty-eight percent of the patients had had previous orthodontic treatment before the presurgical orthodontic treatment. Nine of the Class II patients had anterior open bites (overbite <0 mm) at the start of treatment (mean overbite, –2.8 mm; range, –11.7 to –0.1 mm).

The method error values varied between 0.43° and 1.56°. Only maxillary incisor inclination (1.56°) and mandibular incisor inclination (1.44°) were greater than 1°. There was evidence of some systematic error with the measurement of lower face height proportion (P = .02), although the method error for this measurement was small at 0.84%.

Treatment procedures

All patients had surgical mandibular advancement carried out by using the bilateral sagittal split osteotomy technique. Bone fixation was achieved by using plates in 52% of the patients, wires in 14%, and screws in 23%, with the remaining patients having various combinations of these methods. Postoperative intermaxillary fixation was with elastics in 84% and wiring in 14% of the patients, with 1 having no intermaxillary fixation. Twelve patients also had genioplasty procedures.

During the surgical orthodontic treatment, 15 patients (17%) had maxillary and mandibular premolar extractions, 7 patients (8%) had only mandibular premolar extractions, and 4 patients (4%) had only maxillary premolar extractions. Before the surgical orthodontic treatment, 19 patients (21%) had had maxillary and mandibular premolar extractions, 3 patients (3%) had only mandibular premolar extractions, and 4 patients (4%) had only maxillary premolar extractions.

The dental and skeletal movements of the incisors and Points A and B are summarized in Table II. The overall mean change in incisor position in the horizontal axis (representing overjet reduction) was 6.7 mm.

Table II. Skeletal and dental movements (mm)

Movement	*Mean*	*SD*	*Minimum*	*Maximum*
Horizontal maxillary incisor	−1.3	3.5	−9.8	7.8
Vertical maxillary incisor	0.7	3.1	−6.9	9.5
Horizontal mandibular incisor	5.4	3.1	−2.0	12.2
Vertical mandibular incisor	4.5	3.6	−3.5	15
Horizontal Point A	−0.3	2.5	−6.1	5.1
Vertical Point A	0.2	2.4	−5.5	6.0
Horizontal Point B	5.0	3.2	−4.0	13.5
Vertical Point B	3.0	3.6	−4.4	13.4

Downward or forward movements indicated by positive values.

Horizontal skeletal advancement of Point B accounted for 75% of the overall overjet reduction. Dentoalveolar retraction of the maxillary incisors accounted for 15% of the overjet reduction, and mandibular incisor advancement accounted for 10%.

Cephalometric changes resulting from treatment

The pretreatment and posttreatment cephalometric data for the whole sample are summarized in Table III. The mean SNB-angle value showed a significant increase toward the ideal, and there were small but significant increases in the vertical skeletal dimensions (maxillary-mandibular planes angle and lower facial proportions). The mean overjet, overbite, and maxillary incisor inclination values were reduced significantly as a result of treatment. Soft-tissue analysis showed overall significant improvement in the unadjusted Holdaway angle. The posttreatment cephalometric values for males and females were compared by using *t* tests. The mean posttreatment ANB angle for females was 1.11° (SD, 3.13°), whereas the mean ANB angle for males was –0.86° (SD, 2.89°). This difference was significant (P = .00). The mean posttreatment maxillary incisor inclination for females was 108.55° (SD, 6.11°), and the mean for males was 112.71° (SD, 6.67°). This difference was also significant (P = .00). No other significant posttreatment cephalometric differences were found between males and females.

The pretreatment parameters most frequently outside the ideal range were overjet, Holdaway angle, maxillary incisor inclination, and overbite (Table IV). After treatment, overjet correction was generally successful, with 72% of the patients having ideal overjets. Skeletal correction was not as successful as overjet correction, with only 42% having ideal ANB angles after treatment, although only 6% had residual increased ANB-angle values. Fifty-three percent of the patients had final SNB angles within the ideal range, and a further 29% finished with larger than ideal SNB-angle measurements. The posttreatment unadjusted Holdaway angle was ideal in 49% of the patients, with 37% still having residual Class II soft-tissue profiles. There was evidence of incomplete incisor decompensation, particularly in the mandibular arch; 28% had final mandibular incisor inclinations above 99° (more than 1 SD above the Eastman normal value). Fourteen patients (15%) had residual anterior open bites at the end of treatment. Of 9 with initial anterior open bites, 4 still had residual open bites at the end of treatment. The Fisher exact test confirmed that a residual open bite was more likely in a patient with an initial open bite (P = .03). Among the 10 patients with residual anterior open bites who did not have initial open bites, the average size of the open bite was 0.8 mm (range, 0.2-2.6 mm).

Posttreatment cephalometric radiographs had been recorded at various times after surgery, and cephalometric outcomes were further analyzed by comparing patients with posttreatment films recorded a year or less after surgery (67%) with those recorded more than a year after surgery. The mean posttreatment overjet and overbite values were significantly larger for the group with later cephalometric films, although the sizes of the mean differences were small. The overjet values were 3.13 mm (SD, 1.65 mm) and 3.88 mm (SD, 1.31 mm) for within 1 year and later films, respectively (P = .03). The corresponding values for overbite were 1.33 mm (SD, 1.50 mm) and 2.04 mm (SD, 1.39 mm) (P = .03). No other significant differences were found.

Predictors of outcomes

Due to the large number of independent variables entered into the regression analyses, only factors reaching statistical significance ($P < .05$) are reported.

An ideal ANB-angle outcome was more likely in females and patients with larger pretreatment ANB angles (Table V). Ideal SNB angles at the end of treatment were less likely in patients with deeper initial overbites (Table VI).

A posttreatment overjet within the ideal range was more likely in patients with larger initial ANB angles (Table VII). Factors associated with ideal overbite correction were the absence of an initial open bite, a longer postsurgical orthodontic phase, and larger initial lower face vertical proportions (Table VIII).

Ideal posttreatment unadjusted Holdaway angles were more likely in females and patients with smaller initial SNA angles. Those with larger final maxillary incisor inclinations and smaller final mandibular incisor inclinations were also more likely to have ideal Holdaway outcomes (Table IX). The mean inclinations of the maxillary and mandibular incisors in ideal Holdaway outcome patients were 111.4° and 93.9°, respectively.

Table III. Pretreatment and posttreatment cephalometric data

	Pretreatment		*Posttreatment*		*Change*		*95% confidence limits of change*		
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SE*	*Lower*	*Upper*	P
SNA angle (°)	79.80	4.48	79.20	4.94	−0.60	0.28	−1.15	−0.05	.03
SNB angle (°)	75.57	3.86	78.81	3.66	3.24	0.23	2.77	3.71	.00
ANB angle (°)	4.24	3.28	0.38	3.17	−3.85	0.25	−4.34	−3.36	.00
MM angle (°)	24.71	7.21	27.39	7.28	2.68	0.34	2.02	3.35	.00
LFH (%)	55.11	2.52	56.49	2.52	1.37	0.14	1.09	1.66	.00
Overjet (mm)	10.68	2.61	3.38	1.58	−7.30	0.30	−7.90	−6.70	.00
Overbite (mm)	3.92	3.59	1.56	1.50	−2.35	0.34	−3.03	−1.68	.00
Maxillary incisor inclination (°)	114.6	10.27	110.07	6.60	−4.61	0.86	−6.32	−2.90	.00
Mandibular incisor inclination (°)	94.86	8.45	95.19	7.31	0.33	0.75	−1.16	1.82	.66
Holdaway angle (°)	17.81	5.34	12.11	4.75	−5.70	0.36	−6.42	−4.98	.00

Table IV. Proportions of patients with cephalometric values within and outside ideal ranges before and after treatment

	Pretreatment			*Posttreatment*		
	Below ideal	*Ideal range*	*Above ideal*	*Below ideal*	*Ideal range*	*Above ideal*
SNA angle	32.2	52.2	15.6	42.2	43.3	14.4
SNB angle	45.6	45.6	8.9	17.8	53.3	28.9
ANB angle	17.8	41.1	41.1	52.2	42.2	5.6
MM	42.2	38.9	18.9	30.0	36.7	33.3
LFH	23.3	53.3	23.3	12.2	42.2	45.6
Overjet	0	0	100.0	4.4	72.4	23.3
Overbite	14.4	32.2	53.3	31.1	64.4	4.4
Mx incisor	13.3	30.0	56.7	14.4	62.2	23.3
Md incisor	18.9	52.2	28.9	14.4	57.8	27.8
Holdaway	2.2	15.6	82.2	14.4	48.9	36.7

Values shown are percentages.

Table V. Logistic regression analysis for ideal outcome for ANB angle

	B	*SE*	*Odds ratio (95% CI)*	P
Initial ANB angle	0.44	0.10	1.55 (1.27-1.89)	.00
Male	−1.38	0.59	0.25 (0.08-0.80)	.02
Constant	−1.88	0.58		

B, Coefficient.

Because the mandibular incisors were still proclined above the normal range after treatment in almost 28% of the patients, a further logistic regression analysis was performed to identify possible explanations for this (Table X). Incomplete decompensation (posttreatment mandibular incisor inclination >99°) was more likely in females and in those with greater pretreatment mandibular incisor proclinations. Further analysis showed that, in patients with residual mandibular incisor compensation after treatment, the mean initial mandibular incisor inclination was 101°. In those with no residual compensation, the mean initial mandibular incisor inclination was 92.5°.

Table VI. Logistic regression analysis for ideal outcome for SNB angle

	B	*SE*	*Odds ratio (95% CI)*	P
Initial overbite	−0.13	0.07	0.88 (0.76-1.00)	.05
Constant	0.67	0.35		

B, Coefficient.

Table VII. Logistic regression analysis for ideal outcome for overjet

	B	*SE*	*Odds ratio (95% CI)*	P
Initial ANB angle	0.21	0.08	1.23 (1.05-1.43)	.01
Constant	0.18	0.36		

B, Coefficient.

Table VIII. Logistic regression analysis for ideal outcome for overbite

	B	*SE*	*Odds ratio (95% CI)*	P
Initial open bite	−3.02	0.95	0.05 (0.01-0.31)	.00
Postsurgical orthodontic phase duration	0.16	0.08	1.17 (1.00-1.38)	.05
Initial lower facial proportion	0.30	0.11	1.35 (1.09-1.68)	.01
Constant	−16.48	6.09		

B, Coefficient.

DISCUSSION

This cephalometric study provided insight into the skeletal, dental, and soft-tissue changes resulting from surgical orthodontic treatment. However, other out-

Table IX. Logistic regression analysis for ideal outcomes for Holdaway angle

	B	*SE*	*Odds ratio (95% CI)*	P
Male	−1.57	.61	0.21 (0.06-0.79)	.01
Pretreatment SNA angle	−0.19	0.06	0.83 (0.73-0.93)	.00
Posttreatment maxillary incisor inclination	0.13	.05	1.14 (1.04-1.25)	.00
Posttreatment mandibular incisor inclination	−.12	.04	0.89 (0.82-0.96)	.00
Constant	−1.57	7.12		

B, Coefficient.

Table X. Logistic regression analysis for mandibular incisors still being compensated at end of treatment

	B	*SE*	*Odds ratio (95% CI)*	P
Male	−1.17	0.60	0.31 (0.09-1.00)	.05
Initial mandibular incisor inclination	0.17	0.04	1.18 (1.09-1.28)	.00
Constant	−16.65	4.09		

comes such as psychosocial changes, occlusal relationships, and alignment, as well as sensory nerve damage, should be addressed in future studies. Posteroanterior views of the skull were not analyzed because this has not gained wide acceptance in the UK,[8] and there are no widely accepted reliable methods of posteroanterior cephalometric analysis. In this study, only patients with initial cephalometric radiographs recorded at a minimum age of 15 years were included. By this age, circumpubertal growth is complete or almost complete,[9] and so the possible confounding effects of facial growth in the analysis were minimized. There was also no evidence that growth assisted improvement because analysis confirmed that patient age at the start of treatment did not influence treatment outcome. Sixty-three percent of the sample was female, and this predominance in surgical orthodontic samples was found in previous studies.[7,10] The ethnic origin of the sample was mostly white (93%), and it is therefore unlikely that racial differences in skeletal and dental parameters influenced the results.

In the UK, surgical orthodontic treatment is carried out almost exclusively by hospital consultant orthodontists and surgeons. The sample included patients treated by a range of clinicians, so it is possible that different treatment techniques might have influenced the outcomes. However, our multi-center study design has the advantage of providing a realistic appraisal of normal clinical practice. Nevertheless, the patients in the sample reflect any variations in record-taking protocols among clinicians. Ideally, all posttreatment films should be recorded after a standard interval, but this was not possible with this retrospective multi-center study that showed wide variations in posttreatment radiographic protocols. Analysis of our findings showed that the means for overjet and overbite differed significantly between patients with postoperative cephalometric films taken less than 1 year and more than 1 year after surgery. Although these differences were small, the larger mean overjet in the later cephalometric group might be interpreted as evidence of some relapse in the posttreatment incisor relationship. It was reported elsewhere that cephalometric changes in surgically treated Class II patients continue beyond 1 year after surgery.[11] After the national outcomes project from which these results were obtained, a standardized record-keeping protocol was designed for use in the UK. This will allow future multi-center research in this area to use time-standardized radiographic records.

The cephalometric measurements that we analyzed described the main skeletal, dental, and soft-tissue changes as a result of treatment. The study sample was defined on the basis of a pretreatment overjet of 6 mm or greater. Overjet correction resulting from treatment was generally successful, with 76% of patients having posttreatment overjets of 4 mm or less. Achieving an ideal overjet was more likely in patients with larger initial ANB-angle discrepancies. The success rate for achieving a full overjet reduction in the current sample was lower than that observed in the study by Proffit et al,[7] who reported that, up to 1 year after treatment, 95% of 57 surgically treated Class II patients had overjets of 1 to 4 mm. The larger proportion of patients in our study with residual overjets of more than 4 mm has several possible explanations. A significant proportion of these patients had cephalometric films assessed beyond 1 year after surgery, and this subgroup had slightly larger overjets, suggesting that there might have been more time for relapse to occur in overjet correction. Furthermore, the mean pretreatment overjet in our study was 10.5 mm compared with 9 mm in the study by Proffit et al,[7] indicating that our sample contained more severe cases. A further factor might be the inclusion of 29% Class II Division 2 patients in the study by Proffit et al, whereas our sample included only 2 patients with maxillary incisor inclinations of less than 95°.

Examination of the horizontal changes in position of the incisal edges and skeletal Points A and B allowed estimation of the proportion of horizontal incisor correction that could be attributed to surgical and orthodontic movements. This analysis is only an estimation, because Points A and B undergo small amounts of remodeling as a result of orthodontic movements. Nevertheless, approximately 75% of the overall changes resulted from skeletal mandibular advancement, whereas 19% of the changes occurred as a result of orthodontic retraction of the maxillary incisors and alveolar remodeling. A previous study reported that 63% of the observed overjet reductions in Class II mandibular surgery patients was achieved as a result of skeletal changes.[10] The large proportion of correction due to skeletal rather than dental movements should favor soft-tissue profile changes.

The sample included patients with various vertical incisal relationships, and more than half of them had increased pretreatment overbites. This is a common feature of Class II patients, and the current findings support the use of single-jaw mandibular surgery in its correction. Less than 5% of patients had residual deep overbites, although overcorrection of overbites was common. Among 81 patients without initial anterior open bites (overbite of 0 mm or more), 10 had anterior open bite (overbite less than 0 mm) at the end of treatment, although the average of 0.8 mm was small. This might have resulted from a variable combination of surgical and orthodontic overcorrection. Although this study was not designed to examine longitudinal stability, there was evidence that patients with later posttreatment cephalometric films had larger overbites; this could be interpreted as a tendency toward relapse of overbite correction. The success rate in correcting anterior open bites was limited, with only 5 of 9 anterior open bites corrected with surgery. A large proportion of patients had increased posttreatment anterior facial height proportions and mandibular-maxillary planes angles. This is an expected finding in Class II patients treated with surgical mandibular advancement and was also reported in a recent study.[10] Similarly, Proffit et al[7] reported that the mean mandibular plane angle was significantly increased in surgical Class II patients but not in those treated with orthodontics only.

Correction of the anteroposterior skeletal relationships to within the normal range was less successful than overjet correction, with 42% of patients having ideal ANB-angle values at the end of treatment. This is similar to the findings of a recent study of surgically treated Class III patients that reported a 36% success rate in normalizing the ANB angle.[12] Correction of mandibular deficiency was good, with only 18% of patients having SNB-angle values less than 75° at the end of treatment. There was evidence of overcorrection of mandibular advancement, with more than 50% having ANB angles less than 1°. However, examination of the soft-tissue profile as measured by the Holdaway angle did not show many patients with prognathic mandibles at the end of treatment. Only 14% had final Holdaway angles less than 7°; this suggests that in most cases any skeletal overcorrection appeared to be beneficial.

A main aim of the presurgical orthodontic phase is to correct the incisor inclination to normal to allow maximum surgical correction,[13] and the less ideal outcomes for the skeletal relationships might have been at least partially due to inadequate presurgical orthodontic correction of the incisor inclinations. Almost a quarter of the patients had proclined mandibular incisors at the end of treatment (>99°), and arguably this might have restricted the full surgical correction of the skeletal relationships. Examination of the patients' posttreatment soft-tissue profiles showed that less ideal profiles were more common in those with greater proclinations of their mandibular incisors. Incomplete presurgical decompensation of the mandibular incisors has several possible causes, and regression analysis confirmed that this was more likely in female patients and those with greater pretreatment proclinations. In the maxillary arch, 14% of the patients still had significant residual retroclinations of the maxillary incisors (<103°) at the end of treatment, with female patients having significantly more upright maxillary incisors. In the context of the observed larger posttreatment ANB angles in females, it could be postulated that clinicians might be more prepared to accept incomplete mandibular incisor decompensation in females, because a slight residual mandibular deficiency might be more acceptable in female patients than in males. In a recent study of Class III surgical patients, maxillary and mandibular incisor decompensations were reported to be incomplete in 34% and 48%, respectively.[12] These findings demonstrate the difficulties that orthodontists often face in achieving complete decompensation of incisal inclinations in Class II and Class III surgical patients.

Arguably, soft-tissue profile after treatment is an important parameter when judging the success of surgical orthodontic treatment. The soft-tissue outcomes in this study should be viewed in the context of the variations in timing of posttreatment radiographs. Twenty-two patients had radiographs taken earlier than 2 months after surgery when some soft-tissue edema might still have been present, although this would not have affected hard-tissue measurements. For a third of the patients in this study, there was evidence of some residual mandibular retrognathia after surgery. This is a complex area; however, there is clear evidence from these results that incomplete incisor decompensation might contribute to the less ideal outcomes in these patients. The patients with ideal Holdaway values had mean maxillary and mandibular incisor inclinations of 111° and 94°, respectively. Poorer outcomes were associated with smaller maxillary incisor inclinations and larger mandibular incisor inclinations, emphasizing the need for orthodontists to adequately decompensate incisors if ideal soft-tissue outcomes are to be achieved. Although patient perceptions of their facial profile outcomes were not assessed in this study, it is nevertheless reassuring that a previous study indicated that even moderate mandibular profile deficiency can often be regarded as acceptable.[14]

Thirty-four percent of the patients had premolar extractions during the presurgical orthodontic phase. This is a similar proportion to that previously reported in surgical Class II patients.[7] Typically, extractions are carried out more frequently in Class II patients treated with orthodontics only, with 2 previous studies reporting that extractions were used in 92% and 80% of nonsurgical Class II patients, respectively.[7,15] In our study, extractions per se were not associated with ideal cephalometric outcomes or residual incisor compensation.

CONCLUSIONS

1. On average, 75% of the improvement in the horizontal incisor relationship was due to mandibular skeletal changes, whereas dentoalveolar changes accounted for the rest.
2. Incomplete incisor decompensation was relatively frequent and might explain the less successful outcomes in soft-tissue profiles.
3. Less than 5% of the patients had residual deep overbites.
4. Mandibular surgery for anterior open bite correction was associated with poor outcomes.

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